

Four-Meter Pinhole Camera for e-Beam Emittance Measurement

(Project Proposal #81)

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Project Proposal #81 (AOD)

Project Title: 4M Pinhole Camera for e-Beam Emittance Measurement

Objectives: Obtain SR electron beam profiles with high resolution ($\leq 10 \mu\text{m}$).

Background Information:

- Existing task (two-year)
- Started in FY03, no funding in FY04, plan to complete in FY05.
- Machine manager priority: medium.

Benefit to APS: 35-BM X-ray pinhole camera is the workhorse for providing electron beam profile information visually (to users), and quantitatively. Improved resolution is critical for accurate measurement of our **x-ray source brightness**.

Consequence: The existing pinhole camera does not have adequate resolution to support **low-emittance** operation and **pico-second source** development.

Cost: Non-effort cost: \$127 K.

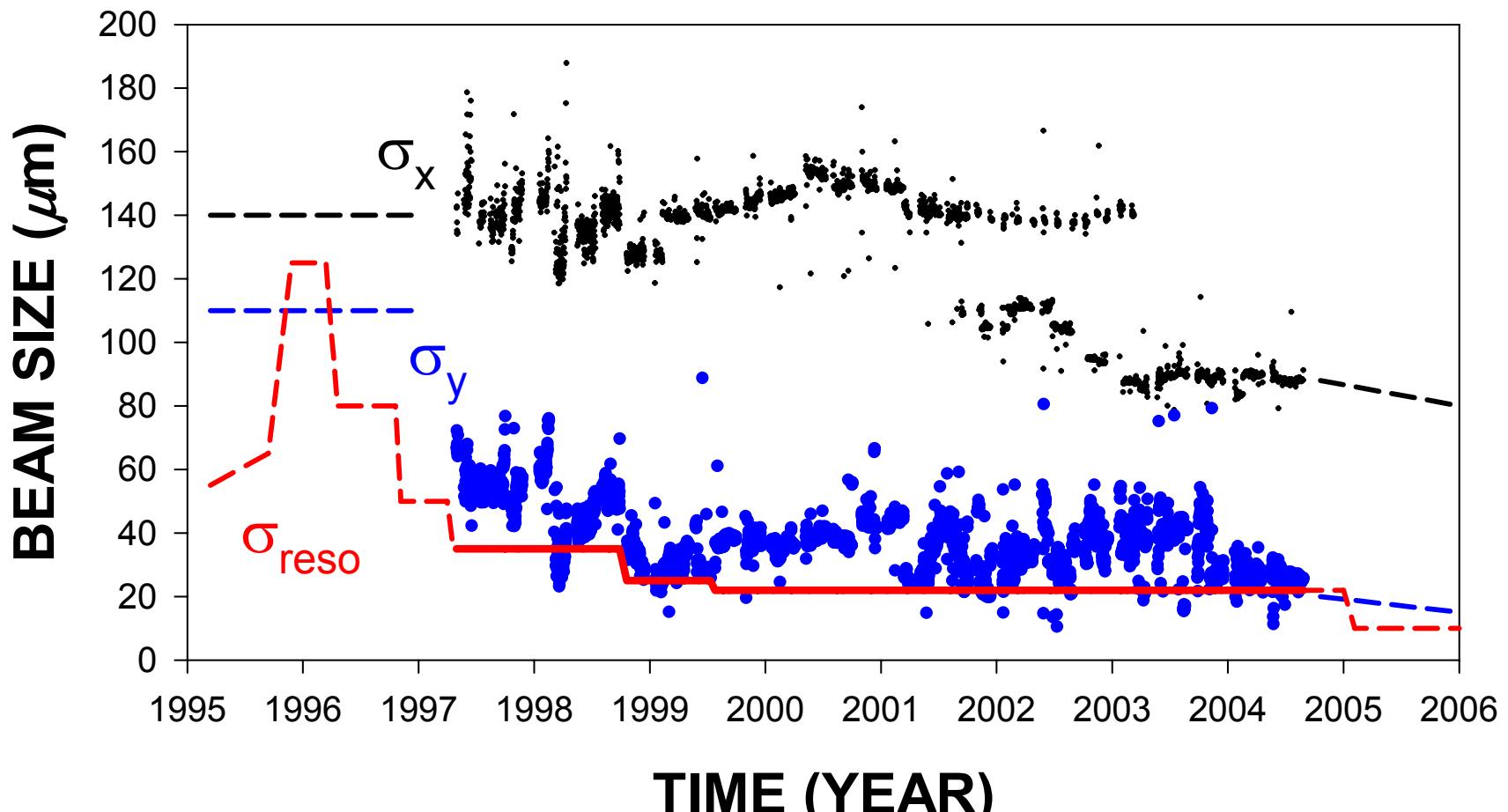
Cost to complete: \$217 K (including effort)

Timing of the Pinhole Camera Project

Why do we need high resolution now?

- Our current camera was built in 1998. Its resolution is $22 \mu\text{m}$, the limit we can reliably image the beam.
- The beam sizes have decreased steadily since then. Typical vertical beam size has come down to low 20's, and stay as low as $17 \mu\text{m}$ for days for some fill patterns.
- The pico-second x-ray source will demand minimum vertical beam size, which the current camera will not be able to measure accurately.
- This is the second part of a project authorized in FY2003. It makes sense financially to complete it in a timely fashion.

Camera Resolution vs. Storage Ring Beam Size

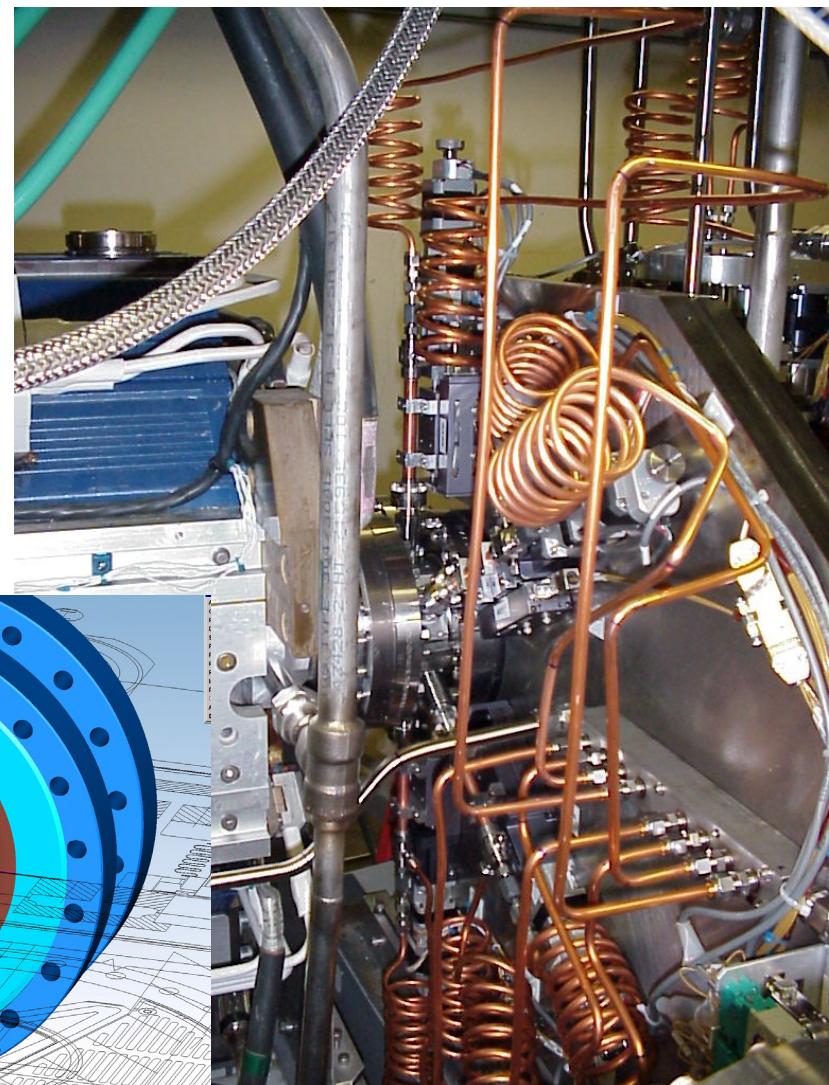
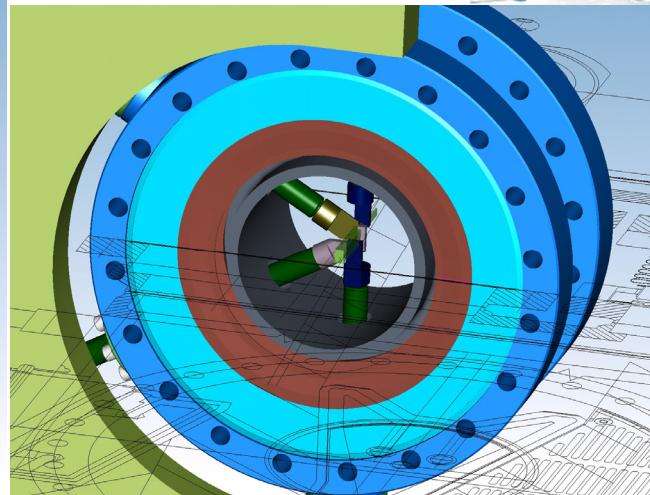
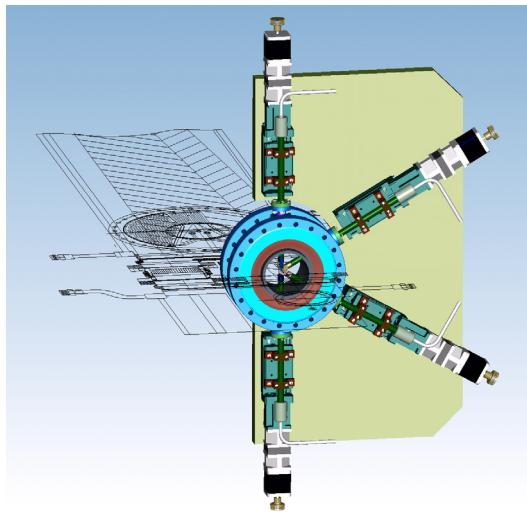


$$\sigma_x = 90 \mu\text{m}, \quad \sigma_y = 17 - 25 \mu\text{m}, \quad \sigma_{reso} = 22 \mu\text{m}$$

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4M Pinhole Camera Project (Phase I, FY2003)

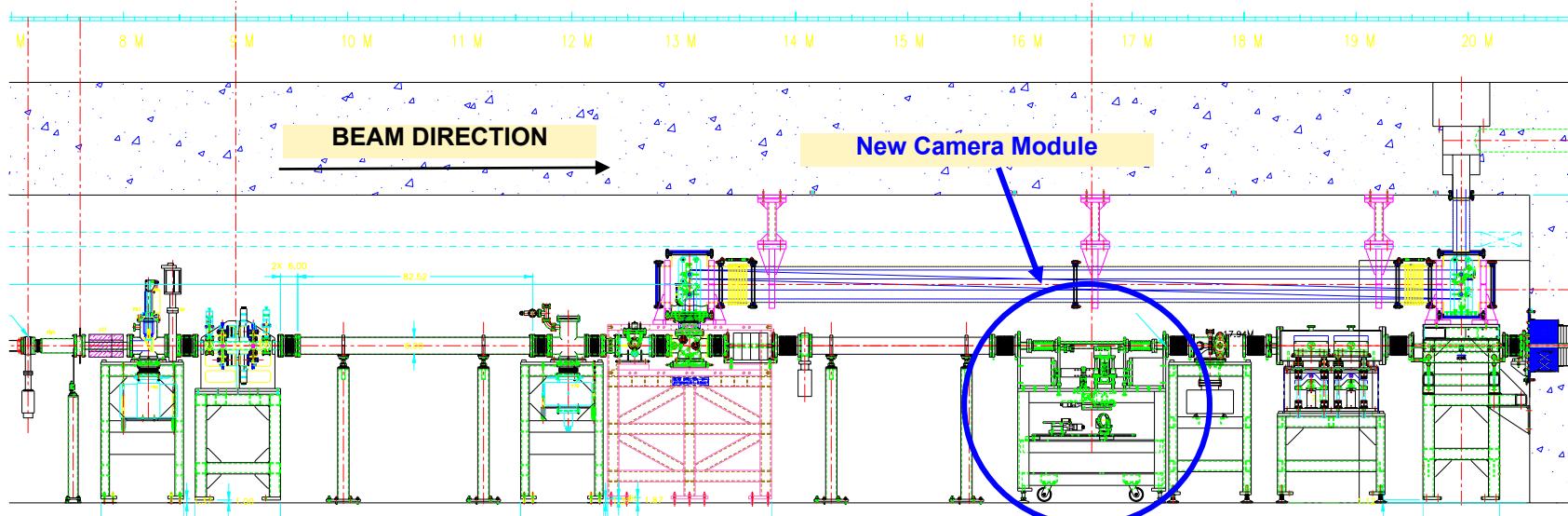
- New pinhole (slits) installed in the storage ring chamber (4 m from the source) in Jan. 2004
- Passed heat load test under x-ray and RF power in the ante chamber for stored current of 100 mA
- Motion control functional



FY05 Request

List of hardware

- Water-cooled support stand for thermal stability ($20 \mu\text{m}/\text{deg}$)
- New scintillator / optics combination (75 – 125 keV x-ray)
- New digital camera (resolution and data rate)
- Control and data acquisition components



35-BM Front End Assembly Drawing

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End of the presentation



35-BM: Workhorse of Emittance Measurements

Pros of X-ray Pinhole Camera

- Inherently safe design: completely inside of the front end, upstream of safety shutter
- Robust operation: simple alignment, good power loading capabilities
- Reliable: ~ 100% availability, including machine studies
- Simple interpretation of real-time images sent to users

Cons

- Indirect measurement, a constant, known beta function is needed for emittance measurement and tuning
- Resolution limited by Fresnel diffraction

$$\text{Transverse phase volume} = \varepsilon_x \cdot \varepsilon_y = \frac{\sigma_x^2}{\beta_x} \cdot \frac{\sigma_y^2}{\beta_y}$$

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Project proposal form

Project Title:

Four-Meter Pinhole Camera for e-Beam Emittance Measurement

Requested by:

Bingxin Yang

Objectives:

Obtain electron beam profiles in the SR at high resolution (< 10 micron) for low-emittance operations

Benefit to APS:

X-ray pinhole camera is used to provide electron beam profile information not only visually, but also quantitatively. The measured e-beam size has been our basis for x-ray source brightness measurements. The new camera will replace the existing one and provide adequate resolution for the beam emittance / source brightness measurements.

Facility Risk Assessment:

The new beamline will replace the existing pinhole camera in 35-BM Front End. No adverse impact to other systems will be generated by this replacement.

Consequence Assessment:

The existing pinhole camera line has been the workhorse of the storage ring emittance measurements since its last upgrade in 1998. With the continued reduction of the beam emittance, the resolution of the beam size measurement (22 um) is no longer adequate for the minimum vertical beam size during storage ring tuning (17 um) and user runs with 324-bunch pattern (20 um during Run 2004-2). Failure to upgrade the beam line will result in recording inaccurate data for beam size / source brightness, impacting both user runs and machine studies.

Project proposal form (continued)

Cost Benefit Assessment:

As a major user facility, we need to know the brightness of the source we are offering to the user. With the strong deconvolution used today, 22 um resolution on 20 um beam size, our knowledge of the source brightness has potentially a 50% error, if not more. It is worthwhile to close the knowledge gap before it widens more as e-beam continues to improve.

Description:

A major upgrade to the existing pinhole camera line was authorized in FY2003. The new pinhole camera line is expected to deliver 10-um resolution in the tunnel with a new detector system, and to 7-um with detectors in the stations on the experimental floor. At the end of 2003, a new set of pinhole slits have been completed and installed in the storage ring chamber at a location 4 m from the 35-BM source point.

This is the second part of the beamline upgrade proposal, which covers a new in-tunnel detector to take advantage of the resolution of the new pinhole slits. The new system includes the following technical components: (1) a water-cooled / temperature-stabilized support stand (thermal motion of the existing steel stand: $dy \sim 20 \text{ um/C}$), (2) new set of filter / optics / camera to realize the calculated resolution, (3) front end vacuum system modification, and finally, if resources allow, (4) a fast camera running at 500 to 1000 Hz to monitor high-frequency beam motion.

Duration of the project:

Complete the detector system 11 month from the starting date or the next shutdown thereafter.